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蔬菜

内源水杨酸参与黄瓜叶片光合系统对低温胁迫的响应

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Role of Endogenous Salicylic Acid in Responding of Cucumber Leaf Photosynthetic Systems to Low Temperature Stress

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摘要 为了探讨内源水杨酸（salicylic acid，SA）在黄瓜幼苗光合系统响应低温胁迫中的作用机制，采用高效液相色谱法测定低温下黄瓜叶片中内源SA 含量的变化；通过SA 合成抑制剂Paclobutrazol（Pac，100 μmol · L^{-1}）喷施和外源SA（50 μmol · L^{-1}）饲喂的方法调节内源SA 含量，并测定不同处理幼苗的叶绿素荧光参数和光合碳同化关键酶基因的转录水平。结果显示：低温引起黄瓜幼苗内源SA 含量升高，Pac 预处理抑制SA 的积累。低温导致PSⅡ的最大光化学效率（*F* v/*F* m）、实际光化学效率（*Φ* PSII）、潜在光化学活性（*F* v/*F* o）和光合电子传递效率（*ETR*）等降低，叶片光化学猝灭参数[（*Y*（*NO*）]升高；内源SA 含量降低使PSⅡ活性下降幅度增大，加重了叶片的光损伤程度。低温下PSⅡ吸收的光能分配于光反应的部分减少，而以非光化学反应的过剩能量耗散Ex 为主要的光能分配途径，内源SA 含量降低会加剧光能向Ex 的分配。低温时喷施Pac 的幼苗中Rubisco 小亚基基因（*RbcS*）和碳酸酐酶基因（*CA*）的表达水平显著低于对照植株。对喷施Pac 的幼苗外源饲喂SA 后，内源SA 含量升高，低温下叶片光合活性得到有效恢复，光损伤降低，光能分配趋于合理，*RbcS* 和*CA* 的表达水平升高。上述结果表明，低温下内源SA 的积累有助于维持黄瓜叶片中较高的光系统活性和碳同化能力，从而保护光合系统，降低低温胁迫对植物的损伤。

关键词： 黄瓜 水杨酸 低温胁迫 光系统Ⅱ 核酮糖－1,5－二磷酸羧化/加氧酶

Abstract： In order to reveal the protective roles of endogenous salicylic acid（SA）on photosynthetic systems in cucumber seedlings under low temperature stress，the seedlings were pretreated with 100 μmol · L^{-1} Paclobutrazol（Pac，an inhibitor of SA biosynthesis）for 24 hours and then cultured at 10 ℃. After 10 hours of temperature treatment，parts of materials were fed with exogenous SA（50 μmol · L^{-1}）. The endogenous SA content，chlorophyll fluorescence parameters，and the relative expression of Rubisco small subunit（*RbcS*）and Carbonic anhydrase（*CA*）genes were determined at different treatment times. The results exhibited that low temperature stress could induce endogenous SA accumulation in cucumber leaves，and this accumulation could be prevented by spraying with Pac. Low temperature resulted in a reduction in maximum photochemical efficiency of PSⅡ（*F* v/*F* m），effective photochemical quantum yield of PSⅡ（*Φ* PSII），potential activities of PSⅡ（*F* v/*F* o），and electron transport rate（*ETR*）. Pac spraying caused a greater reduction in PSⅡefficiency. Low temperature stress led to a decreased allocation of light absorbed by PSⅡantenna to the photochemical reaction and an increased allocation of excessive energy，and Pac-treatment caused a much more allocation of light to dissipation as excessive energy. Also，the expression of *RbcS* and *CA* genes was down-regulated by low temperature stress，and the reduction was greater in Pac-treated seedlings. Furthermore，application of exogenous SA to Pac-treated seedlings alleviated the reduction of photosynthetic efficiency and rescued the repressed gene expression of *RbcS* and *CA*. All of these results suggested that low temperature-induced SA accumulation was required for maintenance of photosynthetic efficiency and carbon assimilation capacity，and thereby protected cucumber seedlings against low temperature-induced damages.

Keywords： cucumber， salicylic acid， low temperature stress， photosystemⅡ （ PS Ⅱ ）， ribulose-1,5-bisphosphate carboxylase/oxygenase（Rubisco）

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